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AUTOKON'S APPROACH TO
INTERACTIVE NESTING

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The paper presents a new approach to the problem of nesting of plane parts. The system developed is tailored for nesting of production parts for shipyards, more specifically those prepared by the AUTOKON 71/74 system. However, the general design is believed to be independent of any particular part-coding system or application.

Geometrically, the problem of nesting is a two-dimensional one, and it is basically similar to any jigsaw puzzle or two-dimensional cutting-stock problem if one disregards all the application considerations that constrain the solution.

The programs developed do not attempt any automatic optimization. The philosophy in designing the system has been that the user is capable of optimizing whatever his objective is, if only the computer is able to supply the appropriate information. Defining and applying the constraints required to do automatic nesting not only becomes difficult, it becomes impossible as constraints on the parts layout change dynamically.

The system was developed and is, so far, implemented on the Norwegian minicomputers NORD-10 and SM-4. The graphics display used is a Tektronix 4014-1 storage tube.

The system is designed to ease conversion to other computers and graphic displays and to interface to other part generation systems with or without databases.

What *were* the goals?

The purpose of this project was two-fold:

To develop an improved system for the nesting of steel plates,

To gain knowledge in the field of Computer Graphics.

By applying techniques in the Computer Graphics area we hoped to:

Reduce the amount of tedious noncreative and error prone work in the nesting process, and therefore maybe increase steel utilization.

Reduce the lead time which seems inherent in the nesting process (waiting to get the job back from the computer, from the drawing-machine).

Incorporate new functions which would be hard or difficult to perform in the manual system (certain types of common cut, manipulation on groups of parts, etc.).

Build a foundation for further development (such as part split, part coding general purpose drafting tools,etc.).

Requirements

Certain major requirements were established at an early point of the specification phase. Some are listed, however, not necessarily in the order of importance.

The system must handle manually coded parts and parts prepared by a computer program (or more specifically the AUTOKON system).

The system must be able to handle an unlimited number of parts.

Functions must be available for displaying single parts (one or more at a time), formats being nested,and details on both of these. The user must be able to page through the part library.

The parts shall be identified and manipulated either by name or by. means of a device pointing at the part image on the screen.

Parts should be displayed with lines drawn differently to distinguish between standard cutting, bevel cutting, common cutting, rapid traverses, punch marking and edge marking. The user must be able to select elements of a certain contour type, both for the purpose of displaying and for referencing.

The user must have functions to modify part production information, such as bevel cutting, common cutting, text, material handling number, thickness, steel quality etc. Functions to modify geometry are part of another module to be developed for part processing.

The user must have flexibility to perform all the basic transformations, translation, rotation, scaling and mirror-imaging, as well as actions combining these basic transformations.

The user must be able to make changes, to store away and to relate groups of nested parts or nested formats. This is important where certain constellations of parts, patterns, repeat.

The user must have functions to check the geometry of single parts or formats and nested formats. Overlap checks between single parts and neighbouring parts are also important to ensure a correct layout. Measurements must also be available.

The cutting sequence shall be specified by the user. The user must have freedom to start a new sequence and end a sequence wherever convenient.

A standard edited NC tape is to be the end product, or the NC information may be fed directly to a NC machine. The user may also store the NC information in the database.

The system must give quick and easily understood responses to all user actions. Production information that may influence the user's next action must at all times be available to the user.

System design

System specifications and programming considerations led to the conclusion that the system comprise three logically distingquishable jobs or phases of operation:

- data preparation and verification (DPREP)
- part layout (LAYUT)
- cutting sequence (CUSEQ)

Purpose of DPREP

The purpose of DPREP is to verify the parts in the database on the minicomputer and to prepare the parts for input to the LAYUT phase. Verification is achieved by displaying the part contours and associated production information (text) with the possibility of generating hard-copies. Data preparation involves reformatting and reorganizing data to meet hardware requirements and optimize data retrieval. (Number of accesses and access times to the database) and data enhancement to minimize core requirements and processing times.

Purpose of LAYUT

The purpose of LAYUT is to place parts together on a format or in a two-dimensional area, taking care of the geometry of what is going to be a nested format. Correcting and verifying completed formats or nested parts is also done in this phase of the system. The geometry of the nested parts will later be the input to the CUSEQ phase.

Purpose of CUSEQ

The purpose of CUSEQ is to specify cutting sequence in order to optimize the use of the flamecutters (torches). The NC information produced is generated on papertape or fed directly to the flame-cutters. A copy of the nested format is stored on the database.

System architecture

On the basis of the system design phase the following system architecture was arrived at (Figure 1).

All command input is handled by the Command Processor. Each Command is interpreted, the corresponding action routine is loaded from mass storage by the segmentation system (if not already in core), before the control is given to the routine. Upon all normal and abnormal (error) exits, control is returned to tune Command Processor.

Each Action routine performs the operation specified by a specific command. To do so it utilizes the following service routines:

> Nest *74* Service Routines provide general facilities needed by more that one action routine.
>
> The Autobase Database System which administers the parts to be nested and system tables of different types.
>
> Tektronix Driver. Routines for driving the Tektronix display.

Hardware

The system Will be implemented on hardware shown in Figure 2, Where the absolute necessities are:

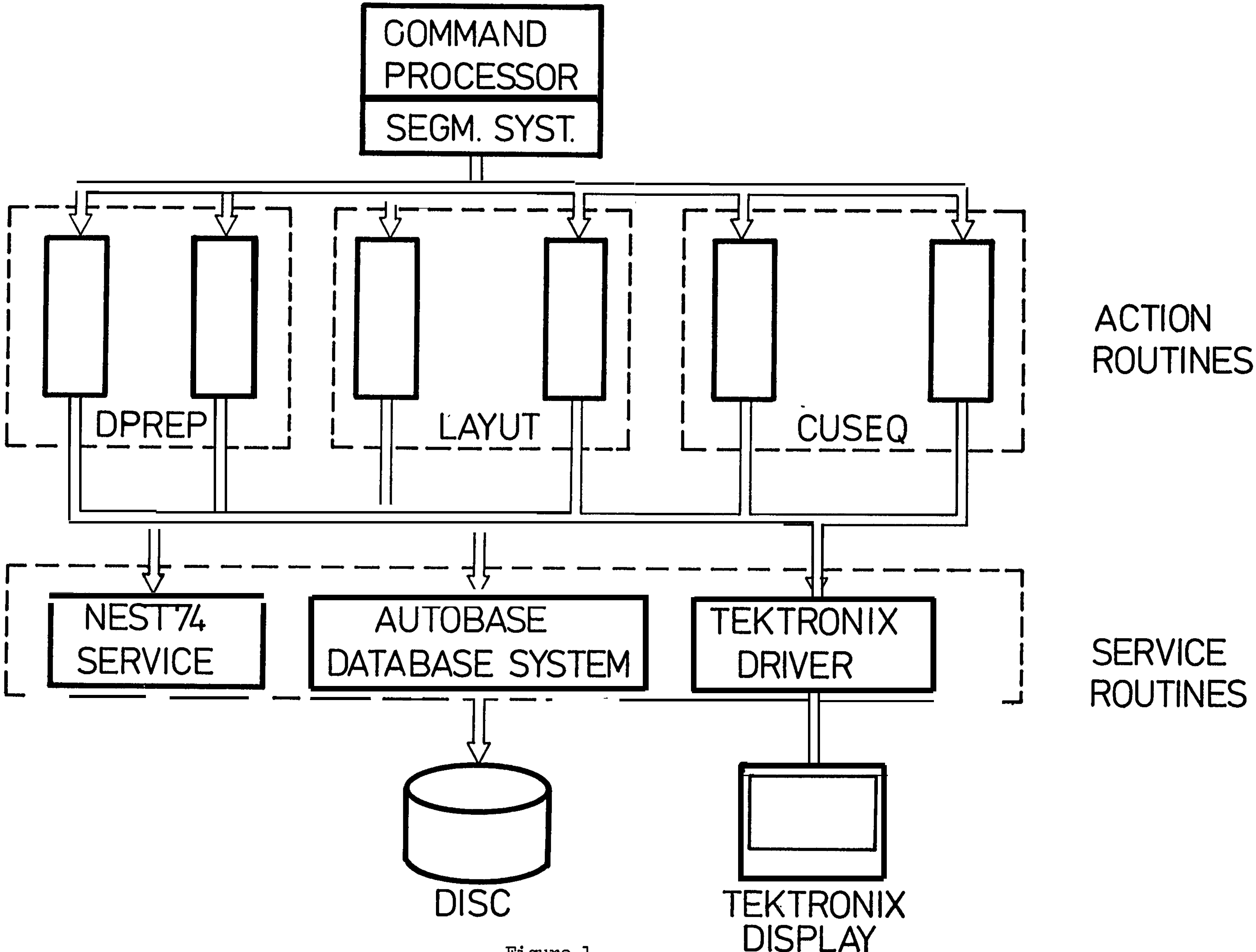
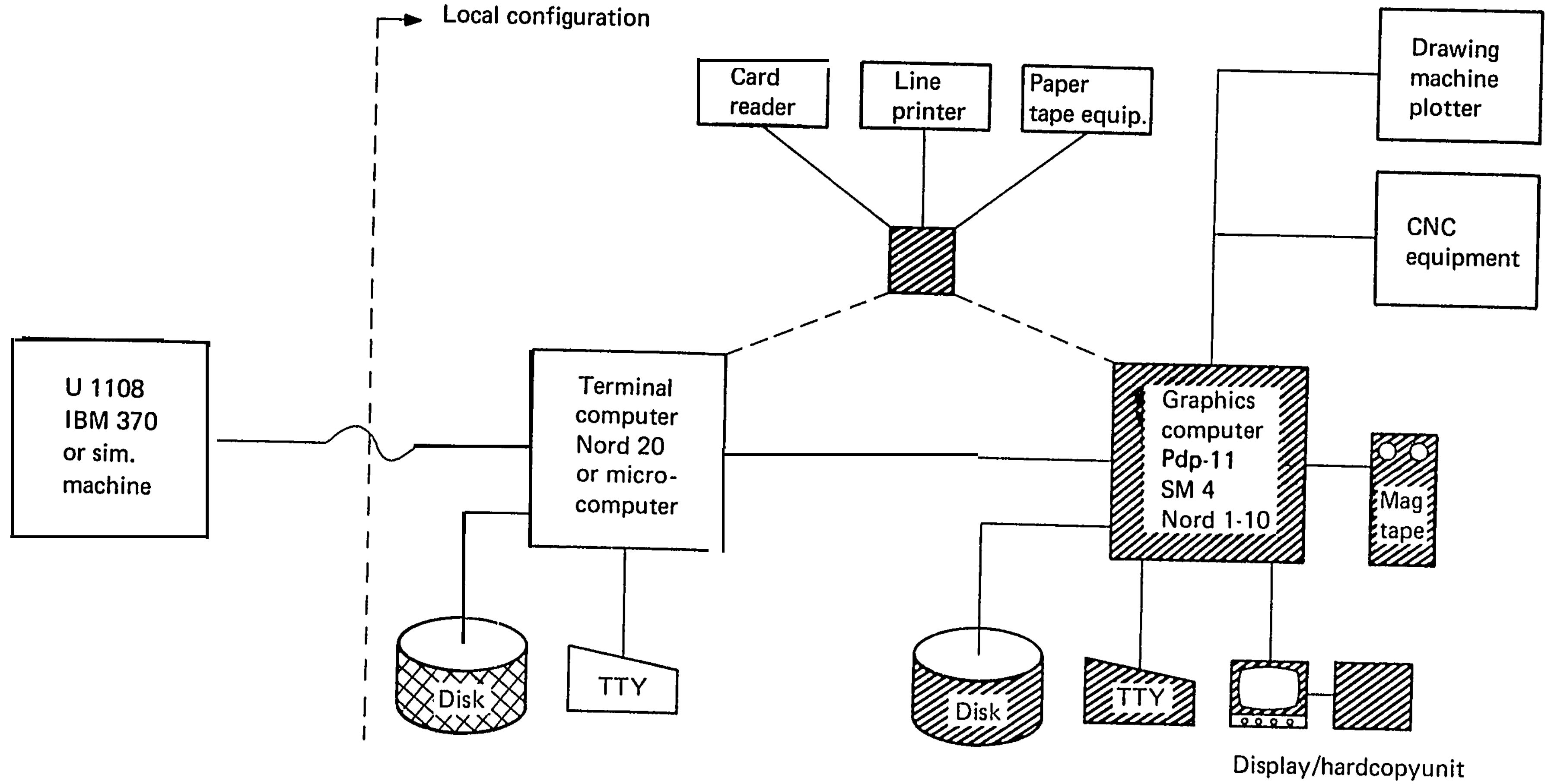

COMMAND PROCESSOR
SEGM. SYST.
DPREP
LAYUT
CUSEQ
ACTION ROUTINES
NEST'74 SERVICE
AUTOBASE DATABASE SYSTEM
TEKTRONIX DRIVER
SERVICE ROUTINES
DISC
TEKTRONIX DISPLAY

Figure 1



Available today

Compulsory for Minicomputer graphics (MCG)

Desirable for database-networks and transmission of large data-files

Figure 2

Minicomputer - (coresize dependent on program organization allowed by basic software - presently 48K).

Disc memory - preferably portable packs.

Tektronix 4014 - 1 Display terminal - hardcopy possibility provided.

Papertape reader/punch.

Teletype.

If the parts are generated on another system a direct connection between the other system and the minicomputer is desirable (Figure 2).

Program and data flow (Fig. 3).

Before the nesting system may be started a database must be built on the minicomputer. This system assumes that the user will work with parts from one section at a time although parts from different sections may be mixed.

The part record in the minicomputer database should contain some information which has previously not been included for AUTOKON, such as:

Cutouts along the outer contour and holes should be marked such that the smooth silhouette contour may be readily retrieved.

Kerf width compensations and shrinkage should be allowed for before the part is used in the DPREP phase.

Once a database of parts is established the DPREP phase may be started. DPREP, upon user request, reads all the pertinent information for a part to be nested, from the part records on the minicomputer database.

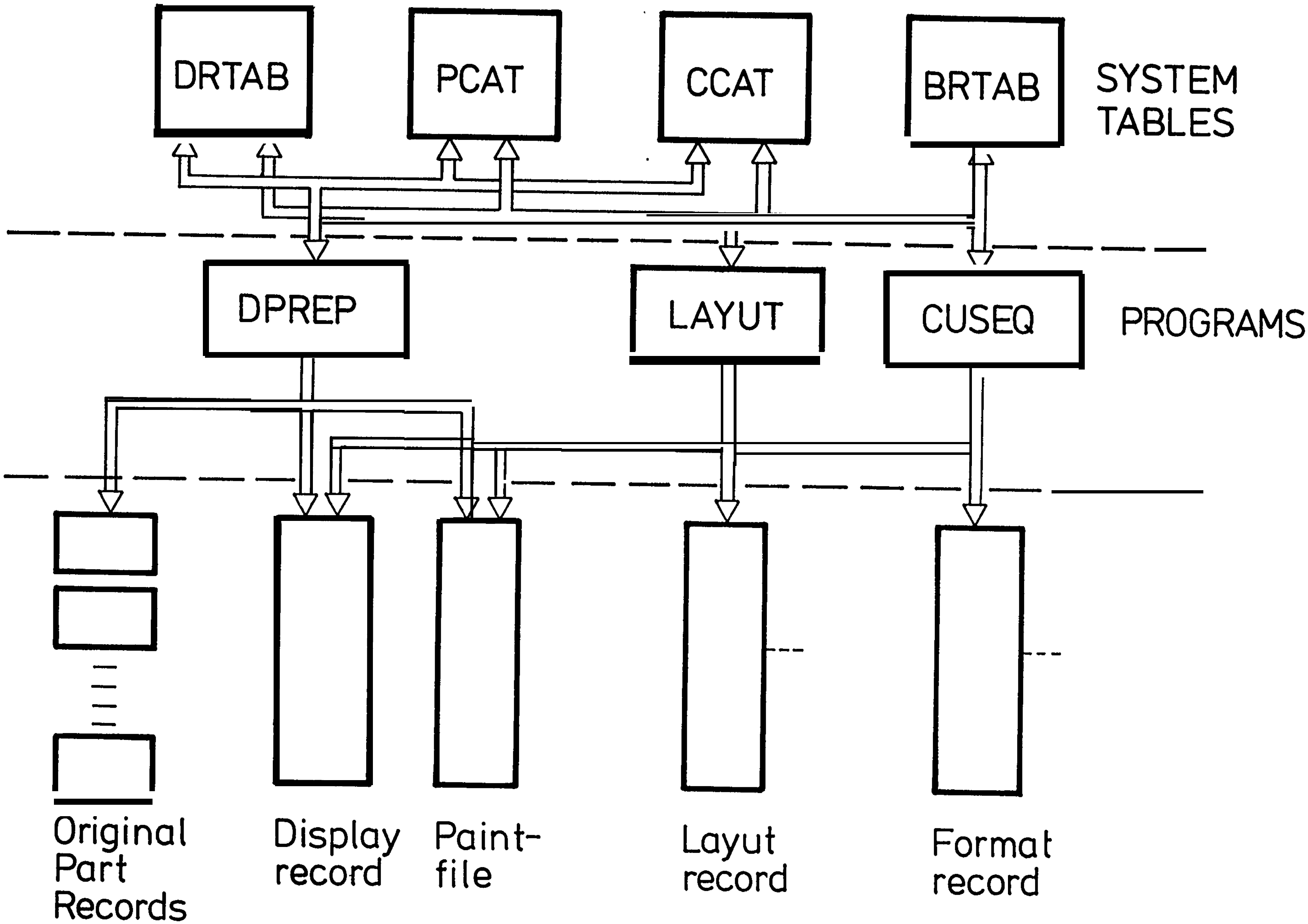

DRTAB
PCAT
CCAT
BRTAB
SYSTEM TABLES
DPREP
LAYUT
CUSEQ
PROGRAMS
Original Part Records
Display record
Paint-file
Layut record
Format record

Figure 3

Before a part may be referenced in the LAYUT phase, it must be passed as qualified for nesting in the DPREP phase. This involves transferring the contour description to a system record, display record. A special table is maintained to control all these parts that have qualified for nesting. This system record associated table is our master reference data whenever a new copy of the part is needed, or when the nested format record is built as an end result of the nesting operation.

There is one more level in the data representation before a part becomes a picture for display. That level is the extracted desired contour parts of the master, with transformations and graphics processing applied. We call this level the paint file representation, since this is an exact copy of the data going to the display driver.

(This is done in order to redraw pictures quickly where minor changes have been introduced, or pictures previously shown, and to allow identification of the different contour elements).

Once the user has verified and prepared the desired parts, the layout of the parts may commence. The user must then change from DPREP to LAYUT phase, and while doing so the system does a lot of background work on the database - garbage collection, back-up, closing old and opening new communication links. Any change of phase has these effects on the database.

At any time, while in the LAYUT phase, the CUSEQ phase may be entered. The user may then input cutting sequence information about the parts already nested.

The complete sequential geometry description of a nested format is not built before the user requested NC information for the format. Until then all actions to do layout of the parts and specification of the cutting sequence result in parameters being stored in special system records. In this way the parameters are maintained throughout and changes are easily achieved.

Using the system

We have attempted to arrange the different commands available to the user into logical groups based on the type of action they perform.

Commands for entering parts to or dropping parts from the nesting system:

PARTS - in the DPREP phase the PART command prepares a part for nesting by entering the part in system contents table

in the LAYUT phase the PART command will display the part in menu area (see Fig. 4).

DROP - removes a parts entry in the system contents table. The command can also be used to remove records from the database.

Commands for specifying formats and the layout of parts:

FORMAT - allows the user to specify a specific format size. The command is also used for:

recalling “old” formats
changing a format
shrinking a format around already
nested parts
removing formats

FRAME To slide the format across the screen. Used to get the desired section of a large format on the screen.

MOVE To translate a part from one position on the format or menu area to another position on the format. The movement is given by the crosshair cursor.

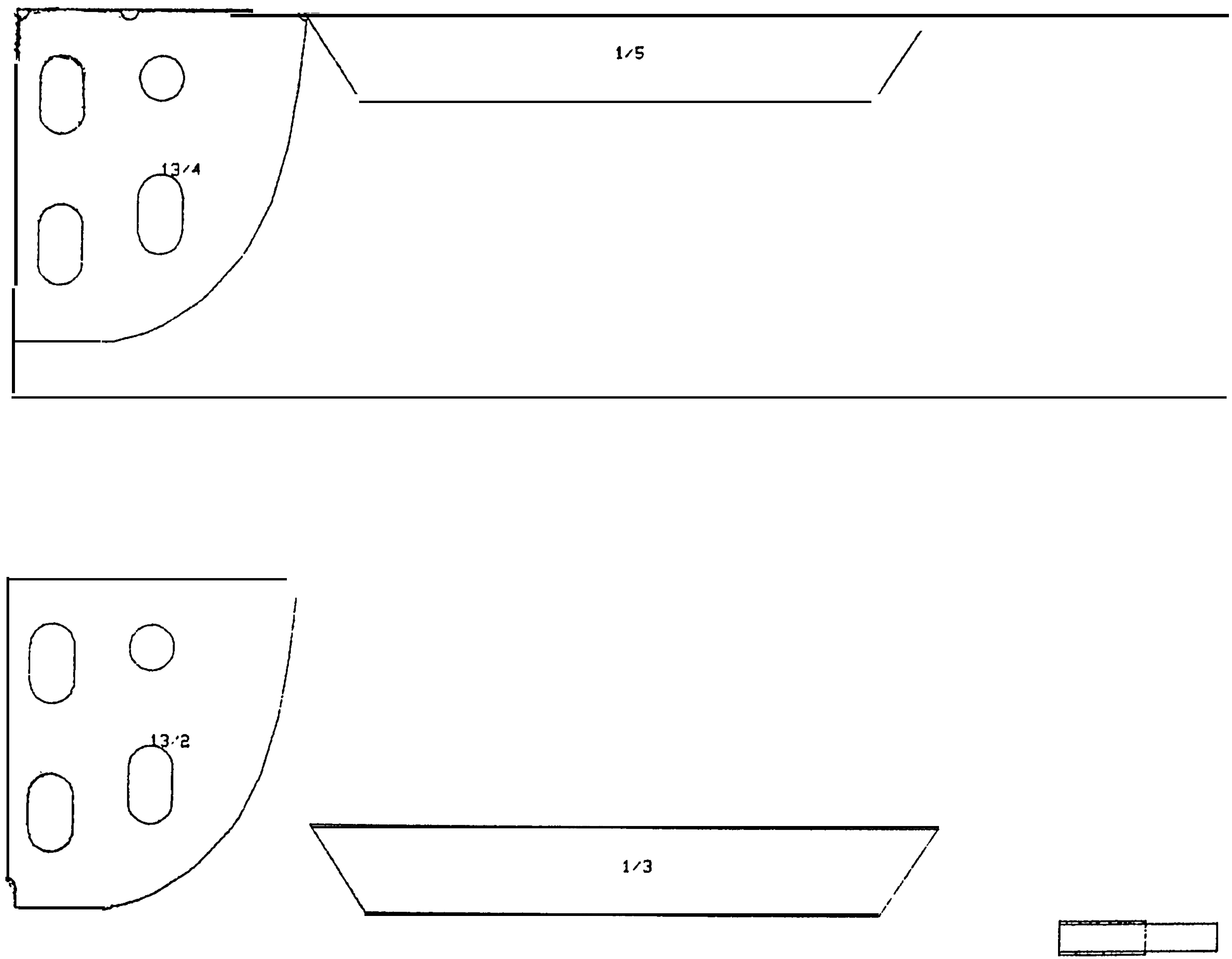


Figure 4

ROTATE To rotate a part. The user identifies the point of rotation and the ange of rotation by crosshair input or by giving the angle in degrees.

MIRROR To mirror a part. The user identifies the location of the mirror axis and in which plane the part is to be mirrored.

PLACE Allows the user to specify a transformation (or a parts position) relative to the format edge or any other part such as placing two parts at a predefined distance for common cutting.

CHECK To check for overlap between parts (not needed when parts are positioned by the PLACE command).

REMOVE To remove or erase parts from a format.

Commands for displaying pictures and measurements:

SHOW To display on the screen

single parts

details

complete formats (squeezed to fit inside the screen area)

RESHOW To reshow (or redisplay) pictures previously generated by the "show" command. Allows the user to reshow the last detail, single picture framed format. (The system keeps track of one level only, ie,last detail).

CLEAN To clean up a messy picture. Redraws the framed format without old copies of parts that have been moved.

DISPLAY To display parts, prestored text, production information and tables. Display differs from the show command by allowing the user to page through the parts visualizing up to 4 parts at one time (see Fig. 5).

DIMENSION To take control measurements from displayed information. Works with the accuracy of the original part description (not limited by the screen accuracy).

Commands for specifying cutting sequence and other production information:

ENTER To specify a cutting tool path that is not included in a contour part description (bridge). Allows the user to specify one- or two-way bridges. The bridges may be horizontal or vertical or the direction may be given by cursor input.

BRIDGE To remove or change bridges on a format. The bridge is identified by pointing with the crosshair cursor.

FOLLOW To trace the cutting sequence of the whole format or any part of a sequence from a user specified point. An illuminated point is used to simulate the cutting tool.

NEW To specify a new cutting sequence. The total cutting sequence may consist of several uniquely identified sequences.

POSITION To position the cutting tool at a certain position. The position is given by cursor or coordinate input. No bridge is generated. (The command may be used in specifying where a bridge is to start).

RIBBON To specify or change corner loops (given the name ribbon). The corner loops must be stored as contours and referenced by a user selected reference number.

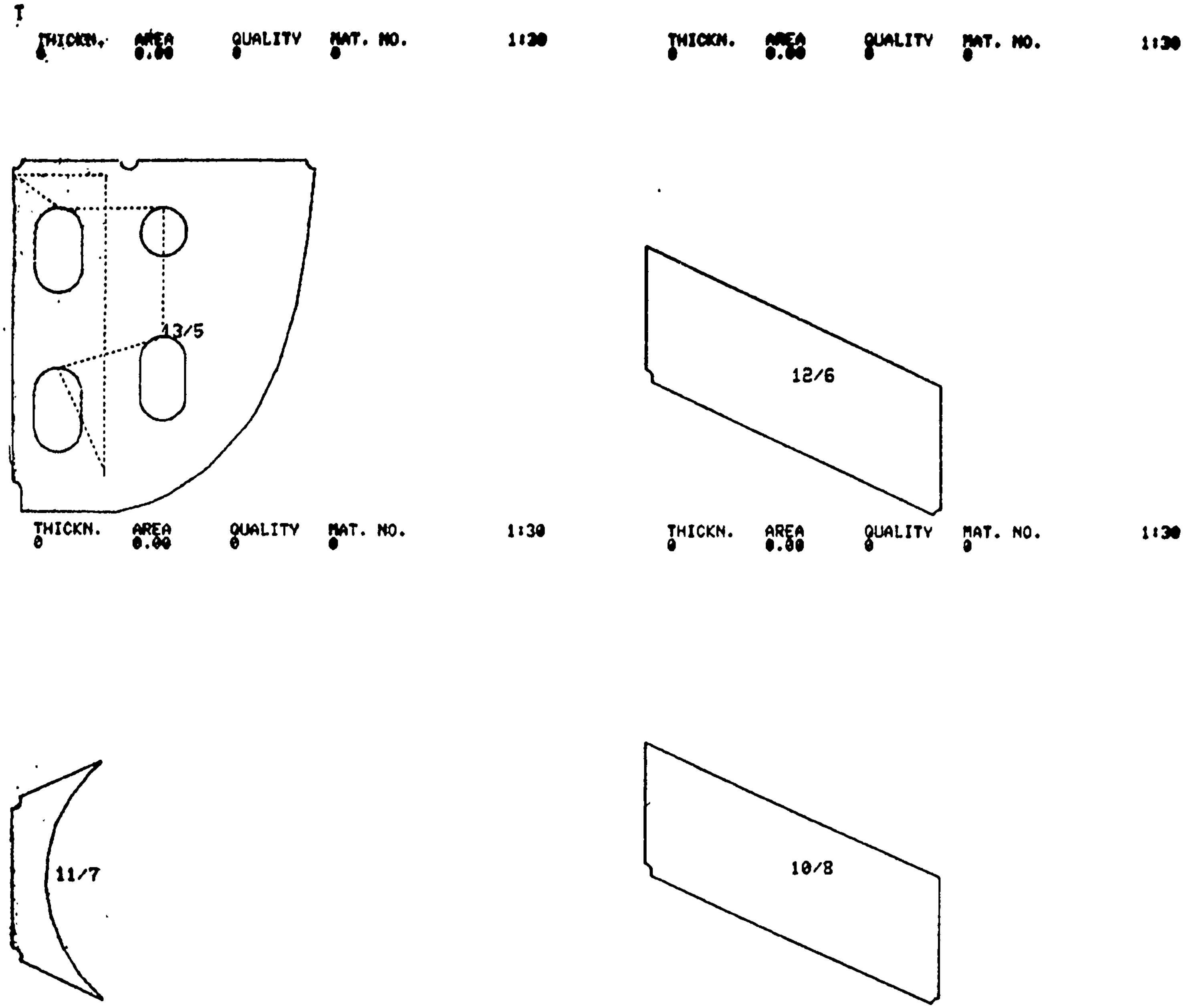

THICKN. AREA QUALITY MAT. NO. 1:30
0 0.00 0 0
THICKN. AREA QUALITY MAT. NO. 1:30
0 0.00 0 0
13/5
12/6
THICKN. AREA QUALITY MAT. NO. 1:30
0 0.00 0 0
THICKN. AREA QUALITY MAT. NO. 1:30
0 0.00 0 0
11/7
10/8

Figure 5

TOOL To specify the cutting tool to be used. Includes facilities to turn torches on and off and to add/modify bevels on a part.

GENERATE To generate the following:

one continous contour of all the parts and the bridges on the format

on the basis of the continous contour to generate a tape for N/C or optical flamecutters.

production information such as steel utilization, cutting lengths, no. of preheats etc.

Commands for specifying system parameters:

CHANGE To change the value of certain system parameters (such as common cutting tolerance etc.).

SET To set scalefactors and other parameters associated with the display on the screen.

SELECT To select contour elements of the part master (original part description) to be used. Used to display a certain contour type and to ensure identification of elements of proper type.

DEFINE To define

texts associated with a picture on the screen

new (user specified) contour types

System utility commands:

HELP To give the user assistance in operating the system. Limited to listing available commands and how they are used.

DUMP To dump system parameters and data areas.

TRACE To set trace of certain system parameters during the execution of the following commands. (The Dump and Trace commands are mainly intended as a help for program development and debugging).

START To start up the system initially or to start a new phase of the system. Any sequence of phase changes is allowed. Garbage collection and database backup taken.

SAVE To save the system temporarily or permanently. The temporary saving of the system involves automatic regeneration of the last picture displayed if the system is restarted in the same phase.

Preliminary Conclusion

Status and experiences

At present the system is operative at CIIR and SRS where a pilot study is being performed in production environment. Based on the experience up to now we feel we safely can say that the Interactive Nesting System represents a definite improvement over the present nesting system. Our experienced “nester” estimates the average time spent on generating a nested format is reduced from 2-3 hours to 15-45 minutes, not including the delay caused by running to-day’s batch jobs and getting the final formats drawn for control purposes.

The task is a demanding one with respect to computer power at the level of accuracy we find necessary. A minicomputer in the upper range of the performance spectrum, (floating point hardware, 64K) is recomended, especially if the system is supposed to be used in a multi-user environment.

The Tektronix 4014 Storage Display seems to be fairly well suited for this type of operation, even if, to a certain extent, it is a dynamic one. The pictures produced on the Tektronix display have the high quality required. However, such systems should be designed with the limitations of storage displays in mind, and a high transmission speed from/to the display is required.

Future development

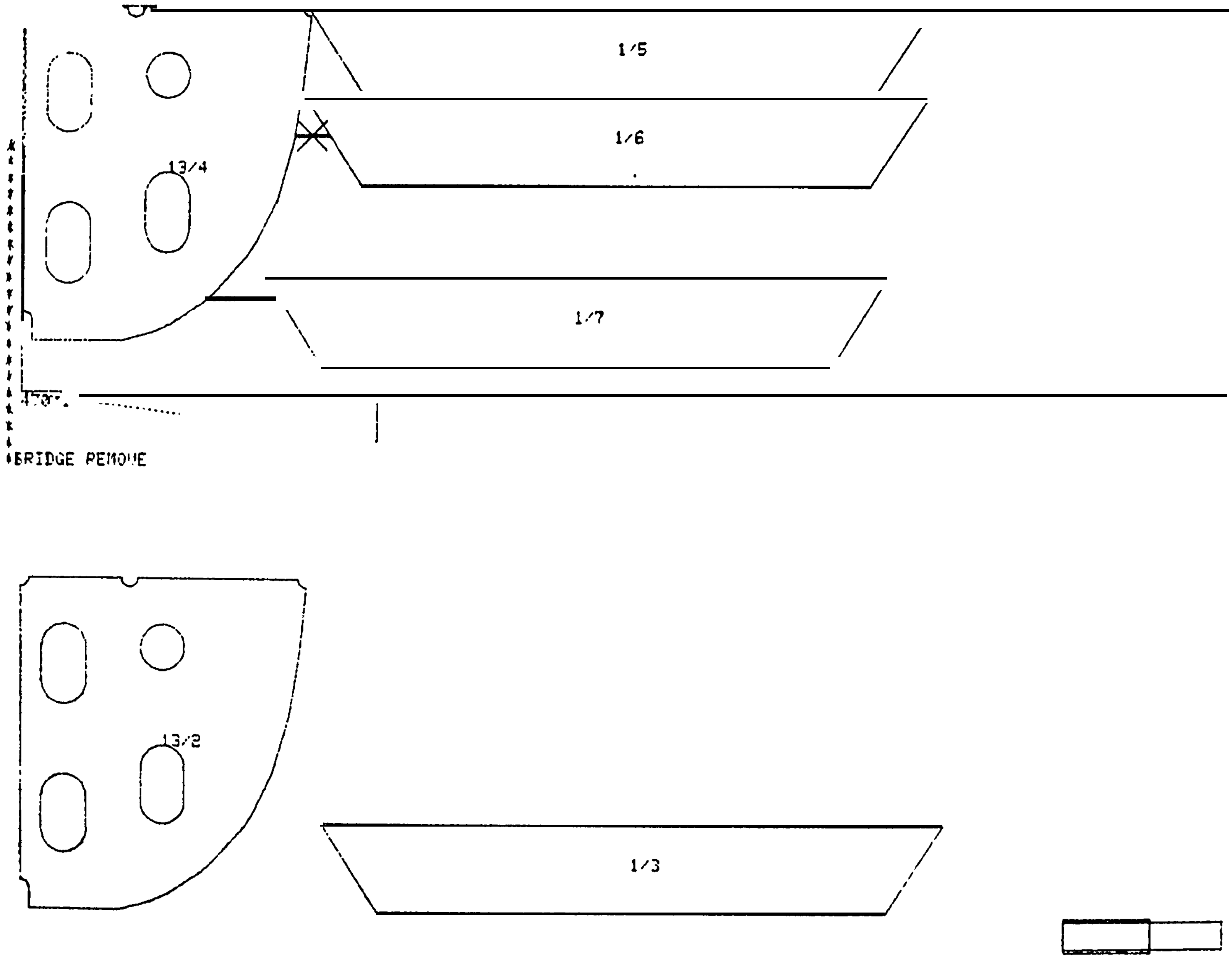
The system design and the programs will be used as the basis for future development in the AUTOKON-line.

At the moment the following two projects have been started:

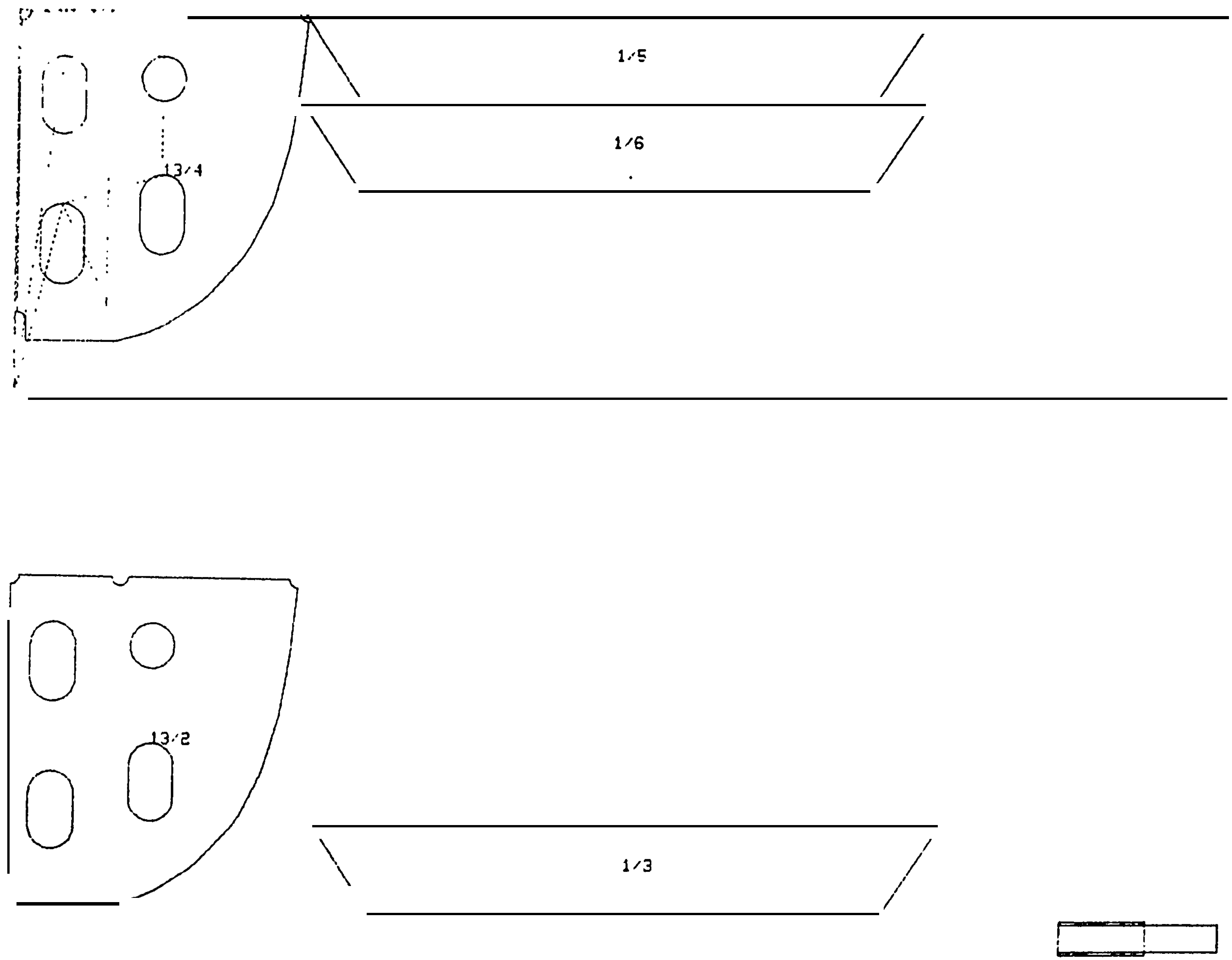
Interactive part splitting/coding

A system for generation of drawings.

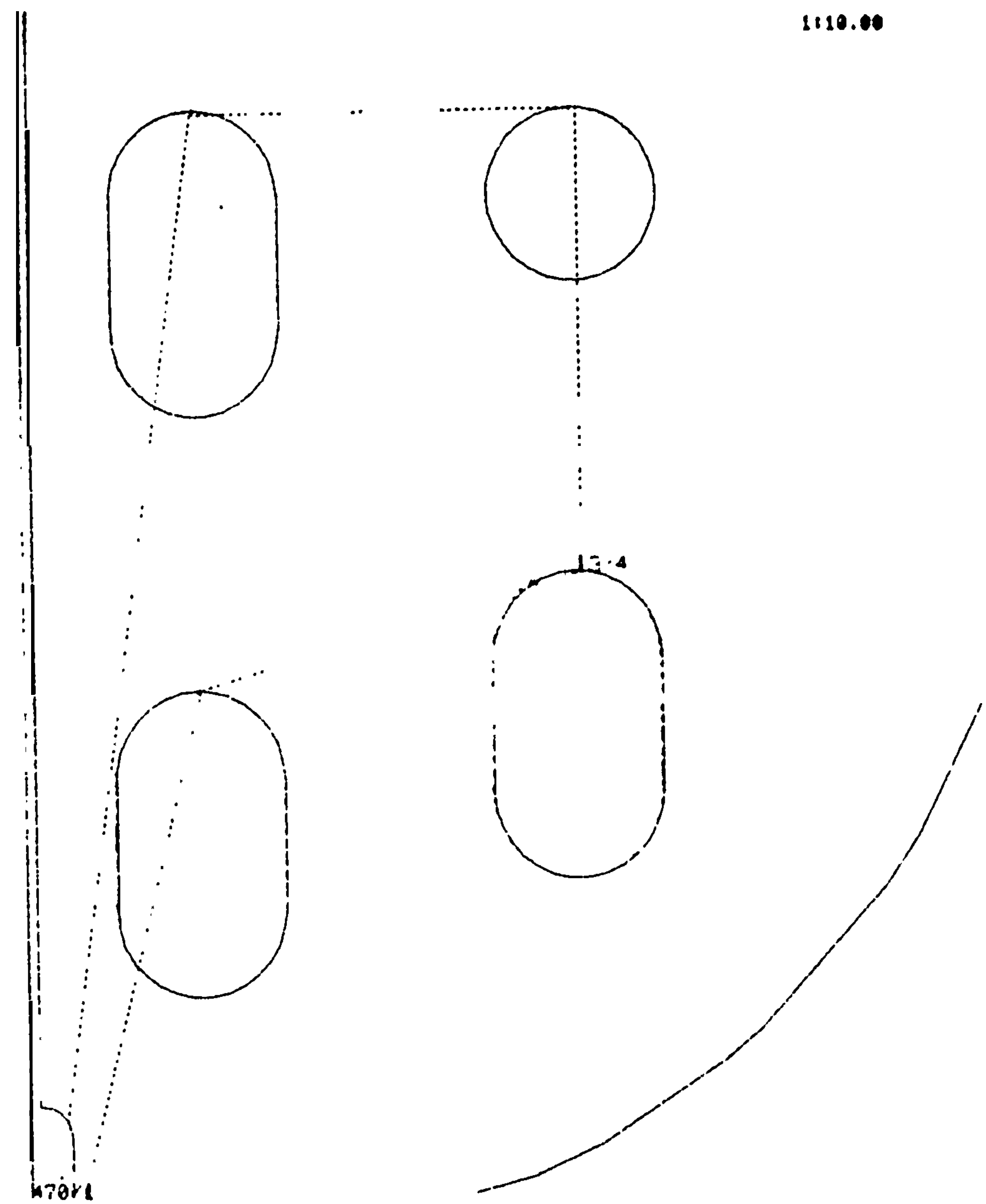
EXAMPLE OF CUTTING SEQUENCE SPECIFICATION



EXAMPLE OF CUTTING SEQUENCE SPECIFICATION



EXAMPLE OF CUTTING SEQUENCE SPECIFICATION



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